WMT

THE McLELLAN ONE METRE TELESCOPE

PROJECT REPORT...

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Note added by Dr William Tobin, 2020 July 23

This Report was written by Graeme Kershaw in 1987.

Two relevant obituaries:

Garry Nankivell (1929-2001)

Norman Rumsey, “Garry Nankivell: Perfectionist.” *Southern Stars*, **41,** No. 1, pp. 14-16 & front cover (2002 March)

Graeme Kershaw (1947-2018)

John Hearnshaw, “Farewell to Graeme Kershaw (1947-2018) – a personal reminiscence.” *Southern Stars*, **57,** No 3, pp. 3-4 & front cover (2018 September)

THE CONCEPT.

Construction of a new large telescope for Mt John observatory was to prove to be an enormous undertaking. Many factors affected the project. Since a successful outcome was essential, if only to justify the cost, time and effort, then several criteria had to be considered before the initial layout design could be undertaken with any certainty. The most obvious point to be evaluated was that of the size of the Primary Mirror. The greatest increase in aperture over that of other instruments currently in use at Mt John Observatory was highly desirable. Apart from optical construction limitations, the following factors were studied to arrive at a sensible size.

1. Workshop limitations.
Previous experience in the reconstruction of a 61cm telescope indicated that severe constraints were imposed on any telescope design that greatly exceeded this figure.

2. Mirror recoating.
Existing facilities for mirror coating could accept mirrors up to 0.8 metres dia. and probably 0.9 metres with minor modifications. This then was the upper limit if the existing plant was to be used with the new instrument.

3. Cost.
Although no numerical ceiling was initially mooted for the construction cost it was essential that it be held to a small fraction of that of a commercial instrument. To make this possible a large percentage of the construction was to be done in the workshops of the Physics Dept. at Canterbury.

THE INTERPRETATION.

It was decided that if a design could be developed that used somewhat smaller units than normal, these units could then be individually constructed and tested in our workshop. The sub assemblies thus produced could later be assembled and the entire telescope tested at a larger local site before installation at the observatory. If the size of these units was kept small, they could also be entirely fabricated, machined and finished using our own facilities thus reducing the actual cost to that of materials only.

The tube of the telescope could be made in three sections. The primary mirror cell, the secondary mirror support system and telescope centre section. These individual items would be linked by a series of tubes in a now widely used layout known as Serrurier trusses.

Another advantage of this concept is that the engineering drawings could be somewhat simplified. Their interpretation by external contractors would not be required. Mating of matching pieces could be easily achieved by the machinist without the precise measurements being supplied on the drawings. Only the large mounting axles would need to be drawn in exact detail for

external contract.

Vacuum aluminizing equipment in the Physics Dept. had a sufficient workload to make removal of this gear to the observatory undesirable, therefore it was decided to build a new plant and install it in the building along with the telescope. This decision made it possible to optimise the coating plant to suit the decided aperture and to the conditions experienced at a remote site.

Having carefully considered these parameters and produced initial sketches, it was decided to settle on an aperture of ONE METRE. The final decision as to upper limit however was then in the hands of the opticians who were to design and construct the primary mirror.

DESIGN PARAMETERS AND LIKELY SOLUTIONS

A complete discussion on the optical design is covered in THE PRIMARY MIRROR FOR THE MOUNT JOHN ONE METRE TELESCOPE. G.R.Nankivell. Physics and Engineering Laboratory. Report No.932. Feb 1986.

After the Opticians had concluded that one metre was an achievable aperture, several further fundamental questions remained to be answered. These questions would set the style for the whole telescope and mounting.

1. Choice of two focal ratios.
Two focal ratios for the telescope (f/13.5 and f/8) would provide greater versatility for the new instrument. Two interchangeable secondary mirror support systems, or an equivalent, would be required to make this practical. Interchangeable secondary support systems have some drawbacks especially in a relatively small observatory. Lifting tackle, in the form of a small dome mounted crane, would be needed to carryout the safe interchange of units weighing many kilograms. Storage of the unmounted unit on the observatory floor would cause unnecessary congestion and leave little room for other instrumentation in the observatory. When a removeable top end assembly is lifted from the telescope an immediate and gross imbalance of the axes occurs. This state can damage drive gears and generally over stress all components.

An innovative system was devised to change the focal ratio. The whole secondary mirror system, including the top end mounting ring, would be mounted on a gimbal. The pivot and clamping points for this ring would also serve as fastening points for the upper trusses. Asymmetry of the support spider would ensure that the respective secondary mirror would be at the correct distance from the pole of the primary mirror. The focus mechanism, motor driven, would be double ended with each end carring a secondary mirror held in position by a quick release mechanism. The redundant mirror would be removed to improve tube balance and avoid the large obstruction of the f/8

secondary mirror during f/13.5 operation.

2. Position of focus.

A Cassegrain focus would be standard on the telescope. Although additional focii were studied, it was decided that incorporation of these would compromise the design advantages so far achieved. A Nasmyth focus, while the simplest option, would introduce an additional reflecting surface, add to system flexure and greatly complicate sky baffle design and construction. A coude focus, though convenient for some observations, was considered unjustified for a telescope of this size. Its insertion loss far offset any other consideration, while the mechanical complexities of such a system would not fit in with the envisaged telescope design.

3. Instrument space.

The choice of telescope mounting would dictate the amount of unrestricted space available for instrument packages. A fork type mounting is an obvious choice for a telescope of this size. It is especially suitable because of its good stiffness and the virtual elimination of a counterweight in R.A. The one major drawback however is that space for instrumentation is extremely limited when the telescope is pointed at or near the pole. There is a practical limit to how long the legs of the fork can be made to overcome this problem and yet retain the stiffnes required.

The observatories Echelle spectrograph, when fitted with the new Photo Diode Array would require 1.5 metres of clear space behind the backplate of the mirror cell. Clearly it would be unwise to restrict access to the polar regions to instruments small enough to fit through the fork of the telescope. A torque tube type mounting, with the telescope offset from the Polar Axis by a counterweighted Declination axle, would overcome this problem. With sufficient care in the design of such a mounting a good degree of stiffness could be achieved.

4. Polar and Declination drive units.

Tracking accuracy of 1 arcsec. in Right Ascension would be required plus slewing, setting and guiding speeds in both axes. Most small telescopes use worm and wheel drives for both axes. One of high precision providing the tracking accuracy required in R.A.. Such a gear would require a tooth to tooth accuracy of 0.0001" accumulating to no more than 0.0005" between any two teeth. To provide the required drive rigidity and strength a gear diameter of about 1.2 metres for the Polar axle and 0.9 metres for Declination would be needed. These gears would have to be imported from some manufacturer with particular expertise in the field of large precision gears. No local engineer had the capability of producing gears to this accuracy. Irrespective of the source, the cost was likely to be considerable.

To obtain the various slewing and guiding speeds it has been customary to use multiple motors combined by a variety of

clutches and differentials. Each motor is then switched in as required and the appropriate clutches activated. The mechanical complexity of this layout causes annoying delays in guiding owing to unavoidable backlash. To avoid this clumsy system and to make computer control possible, it was decided to use one stepper motor on each axle, for all speeds.

The large dynamic range of such motors can easily accommodate the fastest slew (1.5 degrees/sec), tracking (R.A. 15 arcsec/sec), and the slowest guide speed (2 arcsec/sec). Berger-Lahr, a German company, manufacture a series of 5 phase stepper motors capable of 1000 steps per revolution with an absolute minimum of serious resonance regions. The use of these motors in conjunction with a small reduction gearbox would provide a satisfatory solution to the problems of the conventional approach. Discrete steps of the Polar axle would be unresolved at 0.16 arcsec.

5. Position encoding.

Encoding of the axes should be able to position the telescope to +/- 10 arcsecs (1 sec time in R.A.). By using a combination of absolute and incremental encoding, the drive system and the position encoding could be designed in such a way that the encoders could be made locally. This concept was made necessary because of the very high cost of the type of shaft encoder required to give resolution to 10 arcsec.. $NZ 16,000 (1981) was quoted for a pair of 16 bit absolute shaft encoders and these were still short of the necessary resolution.

The idea, most easily described for Declination, was to drill encoding holes in a 300mm dia. aluminium disc. The hole pattern, carrying rotational position, is coded in B.C.D. (Binary Coded Decimal) and arranged in a radial pattern around the edge of the disc. This disc would be attached to a dummy Declination axle and driven by a small worm and wheel directly from the main drive worm. The holes would be read by a row of detectors to give an absolute position readout every 1 degree.

The worm and wheel drive for Declination would have a ratio of 360:1. For every revolution of the worm, the telescope would shift 1 degree. Another disc attached to the worm shaft, and drilled near its edge with 360 small holes each with an apparent angular separation of 10 arcsec in relation to the Declination axle, would provide the incremental readout. The readout could be displayed on the control panel or be available at a port for future computer control. Accuracy of the incremental system is assured by regular checking and updating by the absolute encoding disc on the Declination axle. Similarly, in the event of complete power down of the telescope, shifting of the telescope through only one degree would completely reset all the co-ordinate systems. Focus position encoding would be achieved by incremental counting of the stepper motor pulses, this count would then be displayed on the control console as a number between 000 and 999.

6. Balancing and alignment.

Testing the balance of the telescope axes could be achieved by releasing the worm assembly tangentially on a roller bearing carriage. The motor and gearbox would also move with the worm. The locking clamps holding the carriage would be spring-loaded to absorb any external forces and angular momentum in the event of sudden stalling of the stepper motor.

Accurate balancing of a telescope of this size can be difficult and tedious at best. A likely way to overcome this is to have the absolute minimum of removable balance weights and rely on movable permanent weights, mounted on rails or screws. These woud move in the necessary directions to balance both the Polar and Declination axles. Only two small removable weights would be required to balance for assymetry in the instrument packages.

Exact alignment of the Polar Axis with that of the Earth would be done in two stages, by two separate mechanisms. Approximate alignment could be done by rotating the base of the telescope on the top of the pier. Six large bolts fixed in the concrete and protruding through slotted holes in the base would provide for this azimuth movement. Altitude changes are to be made by simply packing the telescope base to the appropriate angle.

Final alignment, using suitable stars, would be done by pivoting the Polar axle itself about the Spherical Roller Bearing at its top end. The Cam Follower Bearings that support the lower end of the axle would be mounted on a massive cast steel plate. This plate, when shifted horizontally or vertically with the aid of antagonistic screws, would provide the necessary minute movements required to effect precise polar alignment.

7. Dome and Building.

An 8 metre dia. dome would be required. Should this be built locally or imported? What layout and style of building would be needed to house the telescope? For many years, imported aluminized steel domes made by Ash in America, have been in use over the two 61cm telescopes at the observatory. While these domes have given satisfactory service it was felt that their strength in high winds left something to be desired. The estimated cost of a suitable dome of this type for the One Metre telescope was approx. US$35,000 (1980). To build a dome locally, based on an Australian design, was estimated to be slightly over half this figure.

The building proved to be a real problem. Original estimates of the cost made in 1978 were at best unrealistic. Initial plans for a building of about 150 sq. metres would have cost $150,000 (1982), nearly three times the original estimate.

To be built on the observatory car park site, the building had to include, circular telescope accommodation, adjoining aluminizing plant, centralised mechanical and electronic workshops, dark room facilities and office space. A data and control room, with a viewing window through to the telescope, was also envisaged.

The telescope mounting would be bolted to a massive concrete pier 1.7m x 2.1m in section and extending approximately 3m above the observatory floor. To avoid transmitted vibration from the rest of the building the pier would be mechanically isolated from the floor and extend 2m into the rock below the building. High tensile reinforcing rods, grouted into 5m deep drilled holes would provide a positive key to the rock.

A dome, constructed of laminated wooden arches, covered in exterior grade plywood and clad with thin aluminium sheeting would house the telescope. The observing slot 1.8m wide would have a shutter opening vertically. This layout would be needed to provide a low profile to the strong winds experienced at Mt John.

Based on a Australian idea, the dome was then designed by Bruce Bradshaw of the Physics Dept. to suit local materials and facilities. The design was computer analysed by the Ministry of Works to make sure that the structure would withstand wind speeds of 220km per hour. Construction was to be carried out in hanger at Wigram airbase. Storage in this hanger would also be possible until the observatory building was ready to receive the dome.

To facilitate easy access to the instrumentation on the telescope, some mechanical device was required to bridge the gap of 2.5m between the floor and the instrument mounting surface. Ladders, lifts and hoists all had obvious drawbacks, especially when used in the dark. The best solution seemed to be a rising floor. This false floor would occupy the entire observatory area and move up and down as required, carrying the observer and control desk with it. Movement over a range of 4 metres was needed and access would be via a curved stair fixed to the internal wall of the building. The method of elevation could be by cables, hydraulic or screw jacks. It was envisaged that the Physics Workshops would undertake the construction of this item.

An aluminizing plant would have to be built at some time later in the project period. This unit would be completed and installed along with the telescope, using the same lifting equipment. This would allow the mirror to be left uncoated during transportation and installation. Coating would then be carried out only when the telescope was completely ready for testing and commissioning.

OTHER FACTORS.

During early fund raising, S.K.F. NZ Ltd. offered a donation of bearings for the telescope. Lengthy discussion followed and the bearings for the Torque Tube mounting were chosen. Two large Angular Contact bearings were donated for the Declination axle and a massive Spherical Roller Bearing was purchased at cost for the main Polar axle. Three smaller Cam Follower bearings

were also supplied also at cost. These were used to locate the lower end of the Polar axle.

At a time when the project was first being discussed, Mr Jon Hamilton of C.W.F. Hamilton offered assistance to the project in any way that was practical. As fabrication of the mounting components needed to be carried out in a large engineering workshop, Hamilton Engineering was approached. Our original design was to prove costly to construct. After some redesign was carried out by Keith Whitely of their Research and Development section an excellent design was produced which was more rigid and 25% cheaper to build.

These external influences, by virtue of their generosity, completely precluded any possibility of proceeding with the proposed use of the Ziess Pole Universal mounting for the telescope. While this concept had many excellent features, these could not offset the sensibility of accepting the offers outlined above and opting for the more conventional Torque Tube mounting.

The building that housed the Baker Nunn satellite tracking station at Mt John became vacant in September 1983 after the U.S. Airforce closed the station earlier that year. The building was handed over to the N.Z. Government who held the lease on the small piece of land that the building occupied.

This 400 sq. metre building offered the observatory the opportunity to house the new telescope and expand its office, workshop, dining and accommodation facilities into a new and extremely convenient unit. After careful consideration, negotiations took place between the University and the Land Settlement Board for the use and subsequent lease of the land and building. Preliminary plans were prepared by us and the whole task of addition and alteration, handed over to the Ministry of Works and Development. This is a legal requirement for the construction of University buildings. The task of designing the rising floor was also placed in the hands of the Ministry.

THE REALITY.

Drawings of individual telescope sections began at the end of January 1981 with the assembly drawing of the Primary Mirror Cell. Construction of the cell plus the Mirror Support System began upon completion of the detail drawings of each component in February 1981. As each section of the telescope was being constructed, the next section was being designed in detail and final drawings produced. This flow on method was employed throughout the project. Each section followed on from the next so as to maintain continuity of design. Any flaws in the design of the previous section could be allowed for in the next.

In April of 1981 Gary Nankevill, Bruce Bradshaw and myself travelled to Australia. The purpose of this trip was to study telescopes of similar size at Mt Stromlo and Siding Springs

observatories. Of particular value were several lengthy discussion sessions with Herman Werner. Herman, a design engineer, was greatly involved in the design and construction of the 4 metre Anglo Australian Telescope at Siding Springs. As a result of this trip, many useful ideas for the design of our telescope were gathered. Vital information for the dome and vacuum aluminizing plant construction was also gathered. From my own point of view, the experience put the whole project into perspective and removed many of my worries, especially those with regard to size. The confident approach of the Australian engineers was most encouraging.

Upon completion of the Primary Mirror in October 1981 it was possible to test the axial and radial mirror support mechanisms in the cell. The axial support assembly complied well with the rear of the mirror and the collimation adjustment screws worked well. It was very pleasing to find that the axial support provided virtually no radial constraint to the mirror, being able to be moved with just one finger. The mercury tube radial support gave some initial problems owing to tube stretch. Some remachining of the groove in which the tube sat and the addition of a support ring on the upper side of the rubber tube was required. The mirror was then found to be well supported without constraint in all positions. The mirror support, controlled by the judicious adjustment of the volume of mercury in the tube, held the mirror in position to 0.005". These tests were carried out in a pivoting rig made from a modified version of the mirror test bench.

At this time it was necessary to design and construct the first of the encoders. The Electronics Workshop was keen to develop the telescope control system. Since the encoders were fundamental to this, priority was given to their construction. As Declination is the easiest to encode, it was decided to tackle this one first. Development of the electronics proceeded well and about one year later construction of the Hour Angle encoder was started. Early in 1985 the two encoders were joined together to form a dummy telescope. This enabled proper trials of the system to be undertaken.

Encouraged by the success of the mirror cell and the Declination encoder, work proceeded on the design and construction of the rest of the telescope tube. The Secondary Support System, Focus Mechanism, Trusses and Tube Centre Section proceeded without trouble and the entire tube assembly came together in October 1982. Assembly of the tube was essential at this stage as it was impossible to determine the correct location of the truss mounting points by any other means. Incorrect positioning would result in the three major tube components being incorrectly spaced, out of square and displaced from the correct central axis.

Much extra work was carried out during the fabrication of the Centre Section. A serious weak point in this unit could have been at the junction with the Declination axle. Additional webbing of this area was designed and added in before the unit was completed to satisfaction. Flexibility in this area is a real problem in any offset tube design and the results here

were most gratifying. The Tube Assembly was then dismantled and the individual pieces stored until such time as they were required for painting. This was to be immediately prior to testing in the Machines Laboratory of Electrical and Electronic Engineering

Before working drawings of the mounting were started, design and fabrication of the Declination axle was carried out. The Telescope Centre Section was machined to suit this axle, by C.W.F. Hamilton. A quick trial assembly of these two components took place in order to check the accuracy of the machining.

Mid 1983 saw the begining of the design of the components for the mounting. After consultation with Hamilton Engineering a very useful design was developed. Construction of these components began in late 1983 and the first piece, the Polar Axis Support Column, was delivered in February 1984. The triangular mounting base was already constructed and the joining of this with the Support Column proceeded immediately. The size and weight of this unit caused some handling problems and gave us an appreciation of what was in store for us in the ensuing months. The remaining pieces of the mounting, the Tee Piece and the Torque Tube were delivered by the end of June 1984.

The Declination axle, Drive gear and bearings were assembled into the Tee Piece to check the components. The pieces of the balancing system were also added at this stage to confirm the position of their mounting holes. The Tee Piece was later disassembled and stored.

During these trial assemblies a massive fine grain cast iron ring, cast to our pattern arrived from Buchanans Foundry. This ring was to form the interface between the Polar Axis Drive worm and the Torque Tube. Stability of the drive gear depended entirely on the precision and rigidity of the casting. Machining of this casting was both messy and time-consuming. All the mounting components proved satisfactory and fitted together well, after a little fiddling. It was decided that all the necessary testing of these sections was complete and they only needed to be painted before final assembly and testing.

To this stage all the work had been carried out without a hitch and all that was envisaged and described in the section LIKELY SOLUTIONS came together with only minor changes between the concept and the final product. All that remained to be done was to finalise the design of the Stepper Motor Drive Units to meet the parameters derived from the test work carried out by Ross Ritchie in the Electronics Workshop.

The specification of the stepper motors indicated that there should be no problem in attaining speeds up to 3000 rpm. In reality this could only be achieved under certain circumstances. A resonance region at about 1500 rpm caused the motors to stop without warning, however when operating under a small load this problem seemed to disappear. To slew the telescope at 1.8 degrees/sec a gearbox of ratio 26:1 was required between the motor and the worm and wheel if the motor

speed of 3000 rpm was not to be exceeded. A ratio of 20:1 was needed for the Polar Axle drive. This would result in the telescope moving in discrete steps of 0.27 arcsecs however when the Polar Axis drive defaulted to tracking speed, the motor would be driven in half steps, giving steps of 0.135 arcsecs.

Using this information, the gearboxes, worm assemblies, and overload mechanisms were designed and constructed. This work commenced in November 1984 and the units were ready for testing in April 1985. It was immediately evident that the motors would not even drive the worms, let alone the whole telescope at fast slew. Lower speeds were completely satisfactory. Careful testing showed that vibration transmitted back to the motors from the final output gears was interferring with the stepping of the motor causing it to stall. Two modifications were tried, the combination of these cured the problem.

The modifications carried out were as follows. A resiliant coupling was incorporated in the input pinion on the motor shaft. It is of the co-axial type. A pin through the pinion and the shaft, surrounded by a small "O" ring provides rotational flexibility but is radially stiff by virtue of the close fitting bush in the centre of the pinion. The output pinion and gear were found to be of inferior quality. Cut at 16 DP, the course teeth seemed not to be of the correct form thus causing jerky rotation and contributing to the vibration feed back to the motor. New gears of 24 DP were made and lapped in with fine abrasive, the result was a smooth running gear set which thankfully ran to the original specification.

Although the drive units now ran at all speeds it was felt that the output torque was less than desired. Measurements showed that rated torque was being achieved so two further steps were taken. Instead of running the motors on full steps at approximately 25k Hz they were run on half steps giving about 25% more torque. Reducing the final telescope slew speed to 1.5 degrees/sec meant that the motor could be stepped at only 40k Hz resulting in even greater torque output. Only minimal changes to the electronics were needed to achieve these results.

July 1985 saw the begining of the assembly of the major sub assemblies. Firstly the Telescope Centre was bolted to the Declination Axle. The axle was next fitted with the two large Angular Contact bearings, the drive worm wheel and the anti backlash spur gear. This assembly was then fitted into the Tee Piece. The drive assembly, counterweights and the electronics were fitted and the control console connected. This sub assembly was then exhaustively tested before being painted and covered ready for transportation to the Engineering School.

During these trial assemblies it became evident that the original design of the encoder layout was somewhat clumsy and impractical. The encoder units were large and did not fit readily into the space provided. Careful examination of the assembled Declination and Polar axle units indicated that it may be possible to attach the encoder disks directly to their respective axes. New assembly drawings of these items were

produced and showed conclusively that the proposal was realistic. A new, larger Declination absolute encoder disk was constructed to fit over the axle and additional clamps and reader mounts were made. The two incremental disks were able to be fitted into the new configuration without change. The Hour Angle absolute encoder disk and readers were mounted without major change, to the top end of the Torque Tube. While this was convenient for mounting it made access for adjustment awkward and servicing difficult. To ease this problem the electronics board and the readers were designed to be plugged in and located on pegs to ensure accurate relocation after servicing. Subsequent testing showed that the new layout was completely justified in convenience, accessibility and accuracy.

It was realised at the start of the project that a site would be needed to assemble and test the entire telescope before it was installed at the observatory. Four possible sites were suggested on campus. These were, the Warehouse, Civil Engineerings Concrete Lab and Electrical and Electronic Engineerings High Voltage Lab or Machines Lab. Size and availability respectively, eliminated the first two sites. The High Voltage Lab was given close consideration but the crane in the building could move only in one direction. Since the floor space available was not directly under the crane rail, some problems could be forseen in manoeuvring large components into position. Another worry about the use of this space concerned the continued use of the Lab for high voltage testing while the telescope was on site. The drive electronics and control computer would be especially vulnerable to stray high voltages and no simple protection was possible.

Negotiations took place between Dr. Hearnshaw (Physics), and Prof. Bargh (Electrical and Electronic Engineering) early in 1985 for use of the Machines Laboratory. Permission was finally granted for testing of the telescope in the Lab from Sept. 1985 to Jan. 1986. This area proved to be very practical with warm, clean working conditions. The over head crane had a lifting capacity of 3000 Kg and could move to any desired floor position. An internal sunken loading bay made access for heavy equipment and components very easy. A slight lack of working height under the crane was the only problem encountered during installation and testing.

By the beginning of December the telescope was completely assembled and working in the Machines Lab. The most significant procedure carried out during assembly was the setting up of the Polar Alignment Dish. The centre of curvature of the spherical front surface of this dish had to be coincident with the centre of the Spherical Roller bearing. This allows lateral shifting of the Keyhole Plate, to which the drive assembly is mounted, without the loss of mesh of the worm and wheel. This facility greatly simplifies the fine alignment of the Polar Axle.

Because of the difficulty of calculating the moments about the axes, fine tuning of the counterweight assembly was needed. Additional static counterweights were needed to balance the secondary mirror in R.A. and Dec.. Owing to the large mass of the Echelle Spectrograph an additional removable counterweight

was required. Since this was too heavy to man handle, it was constructed in two pieces, each of 16 Kg. The Declination weight locking pins were replaced with screw operated taper pins. These proved easier to locate, lock and remove.

Extensive running tests were carried out until late January 1986. The drives, backlash motors, overload protection and electronics were tested and retested and some minor faults were corrected. Other faults, detected but unevaluated, were left until the telescope was installed at the observatory. This was necessary because actual observations were required to assess the problems in detail and decide on the best method of correction. The area most affected by these considerations was the drive overload assembly in Right Ascension.

A simplified control programme was written by Ross Ritchie to evaluate the performamce of the encoding system. All proceeded well in this area but a number of unforseen anomalies showed up which were corrected as they arose. This was especially true of the control programme. Two conclusions were arrived at on this matter. One was the value of complete assembly and testing of the telescope before shipment, the other, the need for observers to write their own control software around the bones provided. This software can then be tailored to suit the needs of the individual.

Dismantling and transportation was done in four phases. Firstly, all the small and easily handled pieces were removed and stacked. These pieces included the control console (stripped of its racks), 70 lead weights, covers and the primary and secondary mirrors. This equipment was loaded into a 3.5 tonne rental truck and taken to Mt John on a one day trip. The pieces were unloaded and the building evaluated for its readiness to receive the telescope. It was on this trip that the rising floor mechanism failed, putting the installation, scheduled for the following week, in jeopardy. Guarantees of performance were made by the contractors and on the strength of these, installation went ahead as planned.

INSTALLATION

Friday 28th February 1986 saw a large Ministry of Works flat deck truck loaded with all the major telescope components. The Polar Axis Assembly was able to be transported in one unit. This included the triangluar base, the Support Column, the Torque Tube and the main drive worm with its associated bearings. Also included in the load was the vacuum aluminizing plant, its associated pumps and the Hamilton floor crane. All the equipment was covered and the truck was then garaged until Monday 3rd March when it left for the observatory. Bruce Bradshaw travelled with the truck to supervise the unloading. A crane truck was made available by the M.O.W. and this was used to unload the truck on arrival. Smaller components were stored in the observatory or its annex and the Polar Axis and Tee Piece were under cover outside ready for installation the next day. Because of their size, these two items would be lowered

into the observatory through the slot in the dome.

Steve Hemmingsen, Morrie Poulton, John Hearnshaw and myself travelled to the site by departmental vehicle and arrived later in the day, bringing with us a variety of pieces which included the Right Ascension drive unit and the Celestron finder scope. Upon our arrival it was decided to lower the Polar Axis assembly into the dome and bolt it in position. This move was carried out without any problems and gave us a good indication of how to go about installing the much larger Tee Piece the next day. Calm dry weather would be essential if collision with the slot edges was to be avoided. Observatory Superintendant, Mike Clark along with John Baker and Alan Gilmore were always on hand to help as required.

On Tuesday morning Ross Ritchie and Bill Wilson arrived in a rental van with all the electronic racks, computer and support equipment. The Declination drive electronics were required on site at the time of fitting the Tee Piece. Motor drive was needed to move the axle from its transit position to the angle of the end of the Polar axle. Alan Bright and Roger Corbett from the Audio Visual Centre arrived in time to record the lifting and fitting of the Tee Piece. A comprehensive video record of the entire installation procedure and subsequent aluminizing was made.

The trusses and Secondary Support System were fitted next. This had been completed and the crane dispatched by late Tuesday afternoon. The next major item to be fitted was the Primary Mirror and its cell. The first snag encountered was when this assembly was raised on the floor to fit into the lower truss ends. The four conical bolts which fasten the trusses to the mirror cell were very difficult to align and fit. As this was not the case on previous trial assemblies, distortion during packing and transit was considered likely. Although assembly was achieved it was clear that some remedy was needed to make this procedure simple for future dismantling. Removal of this section is required as part of the re-aluminizing procedure. Repositioning of one truss end was sufficient to adjust the relationship of the four mounting points and once achieved, fitting of the mirror cell and the four bolts was simple. Work proceeded with the installation of the static counterweight segments. These were added progressively to keep the telescope in balance at all times during assembly.

Snag number two was encountered when the swing arm weights were fitted and tested. It was found that the bearing shafts had seized during testing, owing to a lack of lubrication and now movement was next to impossible. By the time this was discovered Tuesday had slipped into Wednesday so rectification would take place after some badly needed sleep.

Activities on Wednesday 5th were watched over by a TVNZ news team. The seized shafts were repaired by removing any burred material and Moly. grease used as a lubricant. The whole counterweight system now worked to expectation. Threading of cables through the mounting proceeded well and with the electronics racks installed initial trials of the telescope

were begun by afternoon. When the team left for home on Thursday morning the telescope was functioning the way it was in the Lab. in Christchurch. The next two trips were to be for finishing the aluminizing plant and the coating of the Primary mirror respectively. These trips were scheduled for mid and late March.

ALUMINIZING

Despite the difficulties experienced with the performance of the Aluminizing plant during testing in Christchurch, it proved to be very pleasing after reinstallation at Mt John. The tank pumped down to better than 8 x 10-6 torr in five to six hours, much to the relief of all concerned. Gary Nankivell was in charge of the whole aluminizing procedure and was observed by Steve and myself as time permitted.

Initial washing, to remove general grime, was followed by a wash in Decon 90. That treatment was followed with Balzers substrate cleaner No1. This creamy liquid is spread over the surface of the mirror and allowed to dry, it is then rubbed off the surface with a cloth pad. The principle behind this substance involves the absorption of oils and greases into the dry powder which are then removed when the cleaner is dusted off.

Seventy two staples, each made from 12mm of 18 SWG pure aluminium wire were hung on the tungsten filaments, the mirror was loaded into the pivoting door and the tank made ready for closing. Before this could be done however, a final cleaning of the mirror took place, this time with Balzers No2 cleaner. This is a refined version of the No1 cleaner and is used to remove the last traces of grease from the suface of the mirror immediately before coating. The backing pump was switched on at 4 pm and pumpdown completed by 9 pm. Aluminizing was done immediately to minimise out-gassing of the new insulators and mirror support pads in the tank. Inspection of the mirror after removal from the tank showed an even, unmarked but slightly thin coating. The overall appearance was most pleasing indeed and the thinness of the coat attributed to some loss of aluminium into the filaments as an alloy of tungsten. Over the next 48 hours however, areas of streaks appeared on the mirror surface and these become worse with time. It seems possible that a contaminated cloth may have been used in the final cleaning, leaving streaks on the surface. It seems even more likely, since the whole procedure was carried out under stressful conditions, with two camera crews and observers in the coating room at the same time. The rubber inflatable tyres on the door of the tank would require replacment. They flattened under the extra weight of the mirror causing misalignment of the door locating pins. Steering was also difficult owing to the high lateral friction of the tyres. With the completion of the coating came first light and many hours were spent gazing through the telescope for the first time.

COMMISSIONING AND TESTING.

Now that starlight could be observed through the telescope it became possible to reassess some of the problems first noticed back in the Machines Lab. The first and most serious fault lay in the Right Ascension drive. The moving carriage that formed part of the overload protection, appeared to be flexing under the load of the whole telescope. An indentical unit on the Declination drive appeared to be satisfactory but was under substantially less load. The Right Ascension unit could be made to flex in sympathy with the natural resonance of the telescope and mounting. The angular amplitude of the flexibility amounted to at least 10 arcmins. A dial gauge on the carriage showed a deflection of up to .010" (0.25 mm).

Ten small ball bearings supported the entire load of this unit and it was felt that these bearings were distorting and causing the flexibility. The immediate solution was to remove the whole drive unit and install larger and stronger roller bearings. This work would need to be carried out in Christchurch. An annoying, loudly audible and all pervading vibration was traced to the same drive unit. This vibration also degraded the image in the telescope and was caused by a broad band resonance region in the stepper motor, which coincided with the tracking rate. A resiliant coupling would now be needed on the output shaft of the gearbox to isolate the vibrating motor from the worm shaft. Once in the workshop this work was completed without difficulty and in three weeks the unit was reinstalled.

The vibration from the stepper motor was reduced to an acceptable level and at times was inaudible, but much to our surprise the flexure was still present and of an amplitude similar to before. Tests with the dial gauge showed that the original flexibility had in fact been eliminated and that the problem now lay in the carriage locking shaft. Although the bearings on this shaft were more than adequate the axle was poorly designed and appeared to be loose where it screwed into the lock body. This additional fault was not seen initially because the energy of the telescope was being dissipated in the flexing carriage bearings before it could noticeably affect the locking shaft. Again this unit was removed from the telescope and returned to Christchurch. Additional stiffening of the springs of the shock absorber units was also undertaken before we were satisfied with the overall performance of the Right Ascension drive assembly. Flexure in the unit is now at an acceptable level although substantially more than that of the Declination drive. This is because of the very high inertia and momentum at the Polar Axle.

At this stage further testing was abandoned in order to prepare for the official opening ceremony scheduled for July 11th. The construction of the covers for the counterweight was carried out in Christchurch but fitted and painted on site. Also built at this time was the wooden panelling to cover the bottom end of the pier and protect the worm and wheel drive. The stepper motor drive electronics were also incorporated in this structure.

Cleaning and tidying of the building occupied a lot of time. Not only did we have our own mess to clean up but also the debris left after extensive building modifications. Concrete dust coated every surface in the building and drops of paint and glue were present on most floors. Bad weather and heavy snow falls made working conditions unpleasant. Low temperatures and high humidity made the drying of paint and water very slow.

Snow was still falling on the day of the opening and two bus loads of guests braved extremely cold and somewhat dangerous conditions to take part in the ceremonies. Much credit goes to Mike Clark, whose snow ploughing skills made access to the mountain top possible.

In the months up to Christmas 1986 several more trips were made by Ross to put the finishing touches to the control electronics. This work included running extra cables, designing and building the dome encoding system and revising the construction of the telescope hand paddle.

In recent months some pointing accuracy tests were carried out by Mike Clark and Clive Rowe. The telescope was driven to the coordinates of a series of stars whose positions were well distributed over the hemisphere. The star was then centered on the cross-wires and the new coordinates noted. Once these positions had been corrected for refraction and aberration it was possible to get a feel for the pointing errors of the instrument. A figure of better than +/- 30 arcsecs for most of the positions was obtained indicating that the telescope is mechanically very rigid. Once the nature of the residual errors has been determined it should be possible to reduce these in the control software.

Since this time the telescope has been used to do Photo Electric Photometry and seems to perform very well indeed. Early worries about poor image quality have lessened greatly since it was discovered that the dome was severely overheating, even in cool sunny weather. Turbulent air flowing out the slot in front of the telescope made for very poor local seeing. The dome was originally clad in unpainted aluminium sheet to reflect as much heat as possible but subsequent tests carried out in Christchurch proved that a white painted surface did the job much more effectively. Two test pieces of insulated aluminium sheet, one painted white, were place outside in the sun and the temperature difference measured. The difference was found to be as much as 7 degrees C. when the sun was normal to the surface under calm conditions. This was true even for very low sun angles and low ambient temperatures.

As a result of these tests it was decided to paint the outside of the dome. Fortunately the original curved ladder, used during the dome construction, was still in existence and made an otherwise daunting task quite straight forward. One coat of etch primer, followed by two coats of white acrylic were applied to the wire brushed and sanded aluminium surface. Adhesion seems good except where, in a couple of small areas, traces of silicon sealer remained. The drop in temperature of the inside of the dome was immediate and the consequent

improvement in the observed image quality was obvious.

Recently, mirror handling equipment has been built to remove and transport the primary mirror during aluminizing operations. This equipment consists of a steerable trolley with a hydraulically operated platform. The mirror cell can be supported as it is removed from the telescope then lowered to expose the edge of the primary mirror. Lifting tackle in the aluminizing room is designed to grip the mirror under its edge while the trolley and cell are wheeled clear. The mirror is then lowered into the washing tray in preparation for coating.

At this time (August 1987) only the installation of the F/8 optical system remains to be done. All the optical construction has been completed by Gary Nankivell. The zero powered corrector lens needs a cell built to enable it to be mounted in position in front of the pole of the primary mirror. A suitable sky baffle also needs to be constructed for this unit as well as for the F/8 secondary. The secondary mirror is aluminized and mounted in its cell and when fitted with its baffle will be ready for use.

It is hoped that Gary Nankivell will be available to collimate and evaluate the entire optical system later this year. This will complete the testing of the telescope as a whole.

IN CONCLUSION.

Nine years have passed since the idea of building a large telescope for Mt John Observatory was first considered seriously, and six years since the project was started. In that time several hundred thousand dollars have been spent and about as many trials and tribulations fought and defeated. For my own part in this project I have found it to be the most difficult task I have ever undertaken. In overcoming this difficulty there has been tremendous personal reward, not only in meeting the challenge but in working with a team whose skills, enthusiasm, dedication and deversified talents defy adequate description. The opportunity to be involved in a project of this nature will not, I am sure, be offered again.

The McLELLAN ONE METRE TELESCOPE stands to speak for itself. It is not difficult for even the most ignorant spectator to get a feel for at least some of the effort and organisation required to achieve this end result.

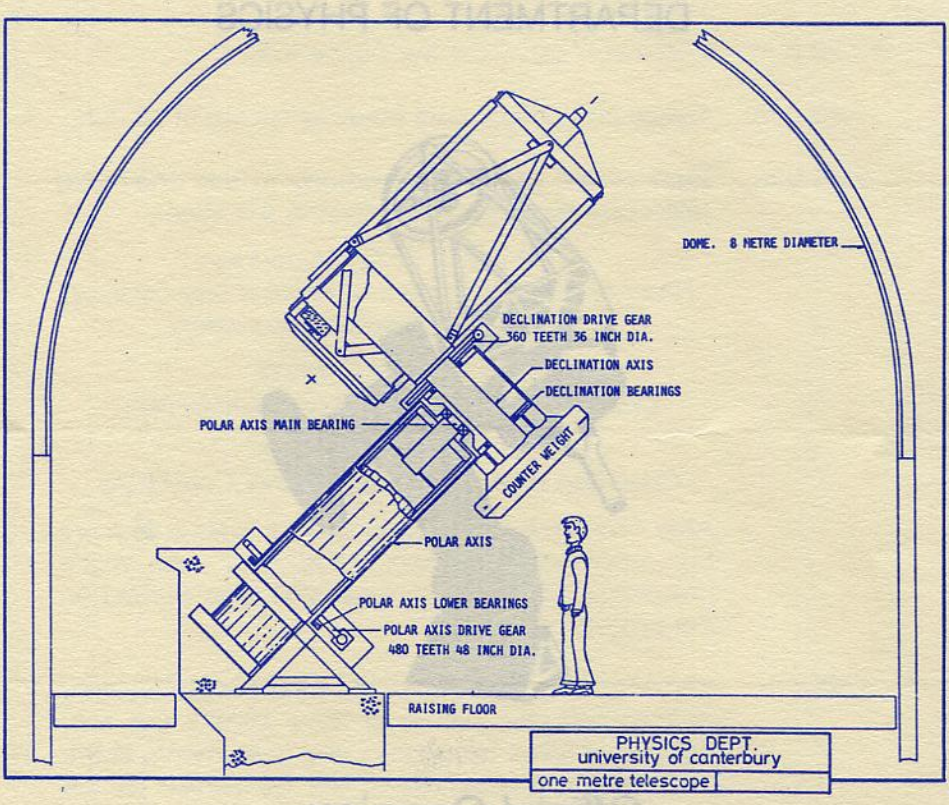
UNIVERSITY OF CANTERBURY

DEPARTMENT OF PHYSICS



Official Opening of the One-Metre Telescope at Mt John University Observatory Lake Tekapo

11th July, 1986


DOME. 8 METRE DIAMETER
DECLINATION DRIVE GEAR
360 TEETH 36 INCH DIA.
DECLINATION AXIS
DECLINATION BEARINGS
POLAR AXIS MAIN BEARING
COUNTER WEIGHT
POLAR AXIS
POLAR AXIS LOWER BEARINGS
POLAR AXIS DRIVE GEAR
480 TEETH 48 INCH DIA.
RAISING FLOOR
PHYSICS DEPT.
university of canterbury
one metre telescope

PROGRAMME

12.10 p.m. Arrival at Tekapo Village. Guests assemble at the Alpine Inn.

12.30 p.m. Luncheon served at the Alpine Inn.

1.45 p.m. Buses and private cars travel to the top of Mt John.

2.00 p.m. Start of the opening ceremony in the one-metre telescope building. The following will speak:

Professor B. G. Wybourne
Head of the Department of Physics and Director of Mt John University Observatory.

Mr C. F. S. Caldwell
Chancellor of the University of Canterbury.

Professor D. Hall
Chairman of the University Grants Committee.

After Professor Hall has unveiled a plaque to mark the opening, Professor Wybourne will make presentations to the technical staff who worked on the project.

3.00 p.m. End of opening ceremony. A visit of the observatory facilities will take place, to show visitors the one-metre and other telescopes and instruments at the observatory. Refreshments will be served in the one-metre canteen on a continuous basis.

4.00 p.m. Buses depart from Mt John. A light snack will be served en route for the convenience of guests, in view of our late arrival in Christchurch.

7.30 p.m. Arrive in Christchurch.